September 17, 2012

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Ms. Marlene Dortch
Secretary
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

Re: Ex Parte Presentation in WT Docket No. 12-70, Service Rules for Advanced Wireless Services in the 2000-2020 MHz and 2180-2200 MHz Bands; ET Docket No. 10-142, Fixed and Mobile Services in the Mobile Satellite Service Bands at 1525-1559 MHz and 1626.5-1660.5 MHz, 1610-1626.5 MHz and 2483.5-2500 MHz, and 2000-2020 MHz and 2180-2200 MHz; and WT Docket No. 04-356, Service Rules for Advanced Wireless Services in the 1915-1920 MHz, 1995-2000 MHz, 2020-2025 MHz and 2175-2180 MHz Bands

Dear Ms. Dortch:

Attached please find the study referenced by DISH Network Corporation in its September 14, 2012 ex parte[1] regarding the substantial interference concerns to the AWS-4 uplink were the Commission to shift the S-Band up 5 MHz to 2005-2025 MHz.

Respectfully submitted,

/s/ Jeffrey H. Blum
Jeffrey H. Blum

cc: Julius Knapp
Tom Peters
John Leibovitz
Blaise Scinto
Robert Nelson
Gardner Foster
Jeremy Marcus
Chris Helzer
Ronald Repasi

[1] Letter from Jeffrey H. Blum, DISH Network, to Marlene H. Dortch, Secretary, FCC, WT Docket Nos. 12-70 and 04-356; ET Docket No. 10-142 (Sept. 14, 2012).

Michael Ha
Stephen Zak

Attachment

S Band Interference from 2025-2110 MHz

September 14, 2012

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Table of Contents

1. Executive Summary

As part of a broader review to enable expanded terrestrial use of the S Band, the Commission requested comment on the feasibility of shifting the S Band uplink blocks to a different location in the band. The proposed location is 2005-2025 MHz, 5 MHz higher in frequency. The shift would place the S Band base station receive frequencies immediately adjacent to high-power BAS and government transmitters above 2025 MHz. Upon review, such a shift would create an interference environment that raises substantial concerns given the nature of the operations above 2025 MHz and the proposed mobile broadband use of the S Band.

Commercial wireless systems generally require frequency separation, or guard band, between base station transmit blocks and base station receive blocks. The guard band provides sufficient frequency separation for the transmitter and receiver filters to roll off and provide improved protection to the receiver.

The frequency separation resulting from the proposed shift to the S Band would mean that the AWS-4 base station receive filter would not be able to reject the strong nearby interference from BAS and government operations.

Base station coordination measures would be insufficient to manage interference, especially in light of the itinerant nature of the ENG transmissions. Exclusion zones to provide increased physical isolation from the interferers would essentially preclude service in the 2020-2025 MHz block in BAS markets or near earth stations.

Greater frequency separation from the high-power transmitters above 2025 MHz is essential to successfully manage the interference. A guard band of 5 MHz is needed to protect S Band receivers from operations above 2025 MHz and provide adequate separation for receiver filter implementation.

2. Spectrum Overview

In March 2012, the Federal Communications Commission released a Notice of Proposed Rulemaking and Notice of Inquiry focused on service rules for the MSS 2 GHz band. The scope of this paper is limited to the use of spectrum above 2025 MHz and its potential impact on the S Band.

2.1 Current 2 GHz Plan

The spectrum allocations in the vicinity of 2 GHz are shown in Figure 2.1.

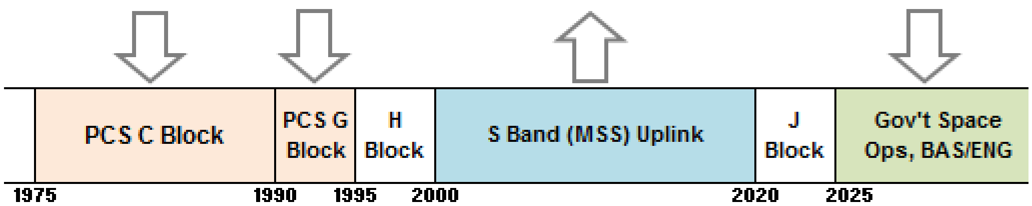

Figure 2.1: Current 2 GHz Uplink Band

The PCS band employs the spectrum below 1995 MHz for base station transmissions. The S Band, allocated for Mobile-Satellite Service (MSS) with an Ancillary Terrestrial Component (ATC), will employ the 2000-2020 MHz spectrum for device transmissions. Notably, the lowest 10 MHz of this allocation overlaps with the global uplink allocation from 1980-2010 MHz.

Spectrum above 2025 MHz is allocated for two purposes. Government earth stations transmit at high power to space vehicles in the 2025-2110 MHz band. The band is also allocated for use by Broadcast Auxiliary Services (BAS) to transmit video from fixed and mobile transmitters back to a centrally located receiver. The mobile transmitters are mounted on Electronic News Gathering (ENG) trucks and often employ high-gain antennas mounted on an extendible mast.

In the current S Band allocation, the 2020-2025 MHz block provided a 5 MHz separation between the S Band base station receivers and the government and BAS high-power transmitters. The 5 MHz separation provided sufficient frequency room for S Band receive filters to reject the strong nearby BAS and government earth station signals.

Similarly, the 1995-2000 MHz block provided a 5 MHz separation between S Band base station receivers and G Block base station transmitters.

2.2 Proposed 2 GHz Band

The AWS-4 NPRM proposes to maintain the existing band plan for the S Band, and the bulk of the FCC's discussion is based on the existing band plan. The Notice does, however, seek comment on the possibility of shifting the S Band uplink higher in frequency by 5 MHz, eliminating the J Block as shown in Figure 2.2.

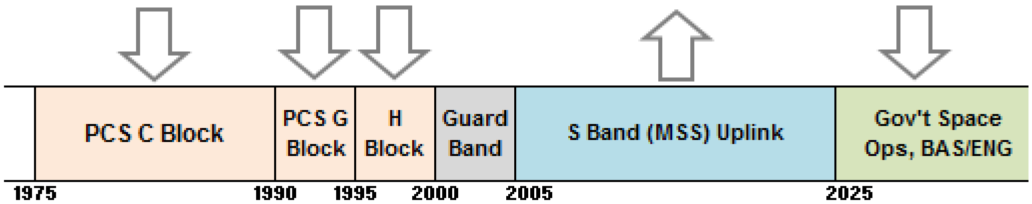

Figure 2.2: Proposed S Band Shift by 5 MHz

One impact of shifting the S Band higher by 5 MHz is the resulting adjacency to transmitters above 2025 MHz. The government earth stations and BAS/ENG transmitters may transmit at high power in close proximity to S Band base station receivers. With no guard band available to enable the design of effective RF filters, significant interference to the S Band base station receivers may result.

The specific interference scenarios encountered at the 2025 MHz boundary is explored further in sections 3 and 4.

3. Broadcast Auxiliary Services

Broadcast Auxiliary Services are regulated under Part 74 of the Commission rules. Fixed BAS stations transmit television program material and related communications from the television studio to the television broadcast tower for transmission over the air. ENG transmissions communicate television material from scenes of events occurring at points removed from the television studio. The ENG trucks provide flexibility of location to the broadcaster, and may be set up anywhere within a metropolitan area. The ENG truck is generally equipped with a telescoping mast, which enables the high-gain antenna to be employed at a taller radiation center, increasing the achievable transmission distance back to the BAS receiver. An example of an ENG truck with mast is shown below in Figure 3.1.

Figure 3.1: Exemplary ENG Truck with Mast and Antenna

BAS operations have a long history of coexistence with commercial terrestrial operations. However, the previous coexistence conditions were considerably different than the current circumstances proposed by a shift of the S Band to be adjacent to 2025 MHz. To fully capture the impact of BAS on the shifted S Band, section 3.1 below describes BAS history. Later sections then describe the technical aspects of BAS operations and the potential interference to shifted S Band operations.

3.1 BAS History

In the 1990's, BAS services extended down to 1990 MHz, adjacent to the PCS base station transmit band. The two services coexisted successfully because the directions of transmission were harmonized. The mobile ENG trucks and the high-power fixed BAS transmitter sites transmitted at high power back to a few central receive sites. The BAS and ENG transmissions were directed above the clutter toward the BAS receive stations, and away from any PCS devices which may have been in operation near the BAS transmitter.

Even with the harmonized transmit directions of PCS and BAS, the potential for PCS base station transmitter interference to BAS receivers existed. Specifically, strong PCS base station transmissions held the potential to overload BAS receivers, or to place spurious emissions within the BAS receive channel and disrupt communications. The C Block PCS operator and the BAS operator coordinated base station placement and antenna orientation to reduce the level of PCS energy present at the BAS receiver.

The small number of BAS receivers within a metropolitan area made this coordination process relatively simple.

Two major spectrum initiatives drove the emergence of the 2 GHz band as shown earlier in Figure 2.1. One initiative was Nextel's SMR re-banding process, which resulted in a return of 800 MHz spectrum to the Commission in exchange for the G Block. The second initiative was the allocation of MSS spectrum. This allocation evolved into the current S Band. The two initiatives elicited the need to re-locate the BAS operations above 2025 MHz, a task handled by Sprint Nextel as a prerequisite to deployment in the G Block.

The re-located BAS band consists of seven 12 MHz channels assigned to 2025.5-2109.5 MHz. There are approximately 100,000 BAS radios employed across the United States. Assuming an even distribution of the radios across the seven BAS channels, the approximate number of radios which may transmit within the lowest 12 MHz channel is (100,000 / 7) = 14,285. This large number of BAS radios poses a significant and complex coordination burden to the proposed S Band deployment. Moreover, the mobile ENG trucks may be set up anywhere within a market, posing an interference risk which cannot be anticipated and planned around. The technical analyses of these interference risks are explored in the following sections.

3.2 S Band Receiver Blocking from BAS Transmitters

The BAS radios transmit at high power and may be located very close to a DISH S Band base station. The edge of the BAS channel may be located at 2025.5 MHz, only 0.5 MHz away from the edge of the DISH base station receive band. This close spectral proximity of a high-power transmitter to a base station receive band poses an S Band base station receiver blocking threat. To understand the potential for interference, we will first examine the performance characteristics of the AWS-4 base station receiver.

The Third Generation Partnership Project (3GPP) is an international organization of standards bodies collaborating to define the specifications for Long Term Evolution (LTE) and other technologies. 3GPP defines radio technology specifications as well as minimum equipment performance specifications.

The 3GPP assumptions regarding minimum base station receiver performance are described in a recent technical contribution by Alcatel Lucent in the RAN Working Group 4.[1] The base station receiver noise floor is first derived as reproduced in Table 3.1 below.

[1] 3GPP TSG RAN WG4 Meeting #60 Athens, Greece, R4-113985 "BS to BS coexistence between Band 12/17 and additional new 716-728 downlink", Alcatel-Lucent, 22-26 August 2011.

Parameter	Value	Units
Thermal noise power spectral density	-174	dBm/Hz
Base station noise figure	5	dB
Noise bandwidth	4.5	MHz
Receiver noise floor	-102.5	dBm

Table 3.1: 3GPP Base Station Receiver Noise Floor

Next, the adjacent channel selectivity of the 3GPP base station receiver is calculated. The adjacent channel selectivity is an expression of the level of rejection provided to the adjacent channel by the base station's baseband and IF filters. The calculation assumes a 6 dB desensitization to the base station receiver when a signal level of -52 dBm is present in the adjacent channel. In section 2.2 of Alcatel-Lucent's contribution, ALU determined that the minimum rejection provided to the adjacent channel is 45.7 dB.

If the base station receive channel is separated in frequency from the interfering transmitter, then additional rejection may be provided by the base station's RF receiver filter. However, RF filters require frequency separation to roll off and attenuate interfering signals. With the BAS transmitter in the adjacent channel, the RF filter will not be able to contribute a meaningful level of attenuation.

Per FCC 74.636, fixed BAS stations are permitted to transmit with an EIRP of +45 dBW. The mobile BAS stations are permitted to transmit with an EIRP of +35 dBW. Converting to dBm, a fixed station may transmit at +75 dBm, and a mobile station may transmit at +65 dBm. Both power levels are higher than the typical 3GPP base station EIRP.

The BAS power level at a DISH S Band base station receiver may be calculated as shown in Table 3.2.

Parameter	Fixed BAS	Mobile BAS	Units	Equations
BAS EIRP	75	65	dBm/12 MHz	a
Distance from BAS to Dish	1	0.2	km	b
FSPL	98.6	84.6	dB	c = 32.45 + 20*log(2025) + 20*log(b)
Dish Antenna Gain	17	17	dBi	d
Cable loss	1	1	dB	e
BAS signal at Dish BS receiver	-7.6	-3.6	dBm/12 MHz	f = a - c + d - e

Table 3.2: BAS Signal Level at Dish Base Station Receiver

The BAS signal level at the DISH base station receiver is much stronger than the level permitted by the minimum 3GPP base station receiver performance specifications. Additional receiver RF filtering is required in order to avoid receiver blocking. The amount of RF filter attenuation required by a DISH base station to avoid degradation, in the case of minimum 3GPP performance specifications, is calculated in Table 3.3.

Parameter	Fixed BAS	Mobile BAS	Units	Equations
Allowed BS receiver interference	-102.5	-102.5	dBm/5 MHz	a
3GPP Minimum BS ACS	45.7	45.7	dB	b
Maximum Adjacent Channel Signal at Receiver	-56.8	-56.8	dBm/5 MHz	c = a + b
BAS signal at Dish BS receiver	-7.6	-3.6	dBm/12 MHz	d
BAS power in 5 MHz	-11.4	-7.4	dBm/5 MHz	e = d + 10*log(5/12)
Required Dish RF filter attenuation	45.4	49.4	dB	f = e - c

Table 3.3: Required S Band Base Station RF Filter Attenuation

The results above may be compared with typical 3GPP device power levels to test the reasonableness of the RF filter attenuation requirements. 3GPP devices may transmit with an EIRP of up to 23 dBm. A device in poor coverage may closely approach a base station operating in the adjacent channel. For a similar separation distance as in the mobile BAS case, the interfering device signal at the base station receiver would be lower than the mobile BAS signal by the difference in EIRPs. The 3GPP calculations also permit 6 dB of degradation to the base station receiver performance, assuming the interferer is a transient device and the interference would not be of long duration. The delta between the 3GPP scenario of a device interfering with a base station and the scenario of a BAS ENG truck interfering with a base station may be calculated as (65 – 23 + 6)) = 48 dB, nearly identical to the protection level calculated in Table 3.3.

In other words, the 3GPP minimum specification was designed to protect the base station from a strong device signal transmitted within a different operator's system in the adjacent channel. Interfering base station transmitters, as with BAS, transmit at much higher power levels than a device, and pose an interference risk to adjacent channel base station receivers. Since a BAS ENG truck may establish an uplink transmitter anywhere within a metropolitan area, each S Band base station receiver must contain an RF filter providing, at least, 49 dB of attenuation to frequencies above 2005.5 MHz.

This protection level is based on the 3GPP minimum performance specifications for the base station receiver, as defined in TS 36.104. LTE vendors typically design their base station receivers more robustly than this level to ensure standards compliance and satisfactory operation in commercial LTE markets. The improved performance of commercial LTE base stations and tradeoffs in RF filter design are discussed later in section 5.

4. Government Space Operations

The United States government operates earth stations, which transmit at high power in the 2025-2110 MHz band. The earth stations communicate with space vehicles in different configurations, including relatively low elevation angles of operation. In this situation, significant earth station energy may be present at an S Band base station receiver. A similar receiver blocking concern as BAS would result for an S Band base station attempting to receive in the 2020-2025 MHz block.

Per ITU-R SA.1154 section 5.1.2, the maximum earth station EIRP at low elevation angles is 47 dBW/4 kHz. Applying similar base station receiver blocking assumptions as in section 3 provides the required base station receiver filtering for a 1 km separation distance, as derived in Table 4.1.

Max ES EIRP	47	dBW
Max ES EIRP	77	dBm
Distance from Earth Station to DISH BS	1	km
Free Space Path Loss	98.6	dB
DISH Antenna Gain	17	dBi
Cable/connector Losses	1	dB
ES power at DISH BS receiver	-5.6	dBm
DISH BS ACS (baseband & IF filtering)	45.7	dB
BS receiver sensitivity	-102.5	dBm
Required BS RF filter attenuation	**51.2**	dB

Table 4.1: S Band Base Station Receiver Blocking by Earth Station Transmissions

The high-power earth station transmissions would require an S Band base station receiver filter capable of achieving 51 dB of attenuation above 2025 MHz.

5. Base Station Filters

Sections 3 and 4 derived base station receiver RF filter requirements of 49.4 to 51.2 dB of attenuation depending on the interference source. The earth station locations are documented; assuming that DISH may plan to achieve a minimum 2 dB of additional isolation from these interferers, the filter design requirement simplifies to the case of the BAS ENG transmitter.

As derived in section 3.2, a BAS ENG transmitter set up 200 meters away from a DISH S Band base station would cause receiver blocking unless the DISH RF filter provided 49.4 dB of attenuation. Of course, the above analysis used the minimum 3GPP performance specifications. As is well documented in other proceedings, commercial wireless equipment is generally designed to exceed the minimum specifications in order to adequately control interference in operational networks. The LTE base station receiver is no exception.

Vendors typically design base station receivers to provide greater adjacent channel selectivity than the minimum 3GPP specifications. The commercial receivers are designed to incur no more than a few tenths of a dB of degradation, in the presence of adjacent channel signals much stronger than the minimum 3GPP level, versus the 6 dB desensitization permitted by the standard.

The combination of stronger allowed adjacent channel interferer and near-elimination of the 6 dB desensitization likely improves ACS performance by as much as 15 dB, for a total protection level of 60.7 dB. Table 5.1 re-calculates the remaining RF filter requirement for the BAS ENG case, assuming up to 15 dB improvement in the base station ACS.

Parameter	Mobile BAS	Units	Equations
Allowed BS receiver interference	-102.5	dBm/5 MHz	a
3GPP Minimum BS ACS	45.7	dB	b
Additional Commercial BS ACS Rejection	15	dB	c
Maximum Adjacent Channel Signal at Receiver	-41.8	dBm/5 MHz	d = a + b + c
BAS signal at Dish BS receiver	-3.6	dBm/12 MHz	e
BAS power in 5 MHz	-7.4	dBm/5 MHz	f = e + 10*log(5/12)
Required Dish RF filter attenuation	34.4	dB	g = f - d

Table 5.1: Commercial LTE Base Station RF Filter Requirement

Thus, an S Band LTE base station receiver operating in 2020-2025 MHz will require an RF filter to provide 34.4 dB of attenuation above 2025 MHz.

Per vendor filter simulations, 34 dB of attenuation is achieved with a 5 MHz guard band. As the guard band is reduced below 5 MHz, the filter implementation becomes more difficult, and significant tradeoffs in filter size and performance are encountered. The performance tradeoffs are of particular importance given the impact to coverage per base station. A change of a dB or two in coverage drives a significant delta in the number of required coverage sites.

In the case of a DISH base station operating in the 2020-2025 MHz block, the proposed band plan does not provide a sufficient guard band from the BAS blocker at 2025.5 MHz. The base station RF filter cannot attenuate the BAS signal sufficiently to prevent receiver blocking.

6. Base Station Coordination

The S Band base station receive block is not alone in potentially requiring coordination to mitigate interference. The S Band base station transmit block from 2180-2200 MHz is adjacent to US government earth station receive frequencies above 2200 MHz. Coordination agreements with the federal government now require the S Band licensee to provide considerable transmit protection to the earth station receivers. This protection requirement may affect S Band base station location and sector orientation.

Fixed BAS transmitters may, to some extent, be taken into consideration in the initial S Band system deployment and subsequent expansions. The S Band RF design may avoid placing base stations within a small radius of the BAS fixed transmitters in order to increase the physical isolation between the transmitter and the receiver. However, the above analysis of fixed BAS interference assumed a 1 kilometer separation, which is likely the maximum separation distance achievable based on a 2 GHz LTE link budget for urban and suburban areas.

Mobile ENG transmitters cannot be coordinated with DISH base stations. Theoretically, the ENG transmissions would occur within subsets of the market consisting of concentric rings, with the high-gain antenna pointing back toward the BAS fixed receive site. This provides some certainty of the direction in which a BAS ENG interferer may arise. Knowledge of the BAS receiver locations could hypothetically permit the S Band base station sectors to be oriented in such a manner that any nearby BAS ENG transmissions would hit the inter-sector null instead of the main antenna beam gain, as shown in Figure 6.1. Sectors facing away from the BAS ENG transmission might then enjoy improved rejection of the interferer by virtue of the reduced base station antenna gain. There are two problems with such an approach: it would be prohibitively inefficient, and it would only mitigate, without solving, the issue.

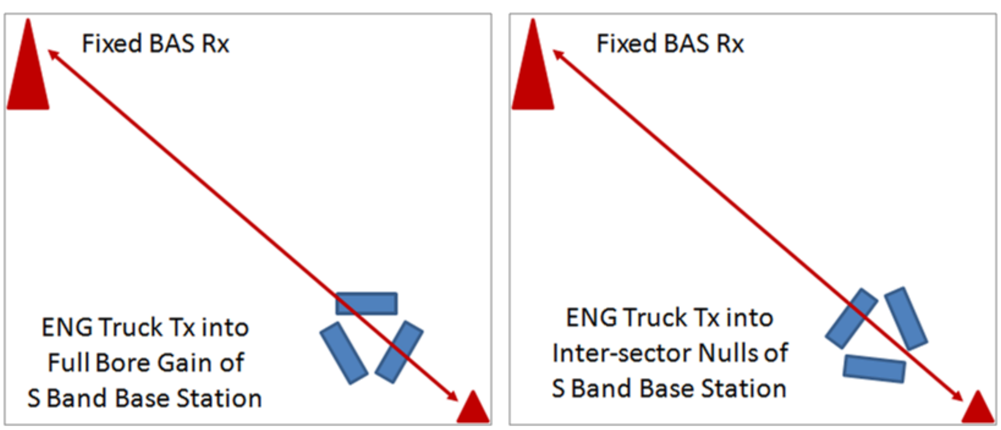

Figure 6.1: S Band Base Station Configurations with Nearby BAS ENG Interferer

As mentioned above, however, the DISH site acquisition and construction process will primarily consider earth station locations as the driver for the sector configuration. It is highly unlikely that the optimal sector configuration to reduce AWS-4 transmit energy to earth stations will also be the optimal sector configuration to limit BAS ENG transmissions into AWS-4 receivers. Such an unlikely possibility will not adequately protect the DISH base station from ENG interference.

In any event, the design approach in Figure 6.1 would provide limited protection even in the optimal scenario of ENG transmission in the middle of the inter-sector null. The base station antenna gain maximizes energy within the main beam of the antenna. Typical 2 GHz system deployments use 65 degree beamwidth antennas in urban and suburban areas to minimize inter-sector interference and increase coverage distance within the main beam. The antenna gain rolls off as a function of azimuth. The minimum antenna gain occurs at the mid-point between the sectors. For a three-sector configuration, the null for a given sector occurs at +/- 60 degrees to the center of the antenna beam.

Figure 6.2 provides a typical 65 degree beamwidth horizontal antenna pattern for a 2 GHz antenna.

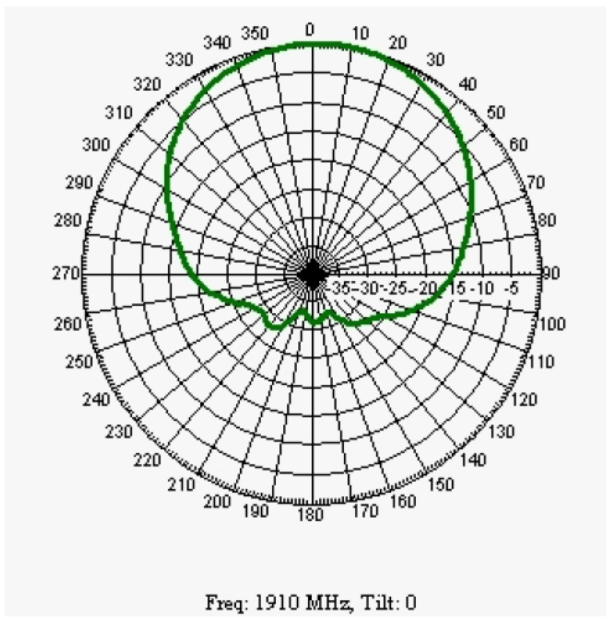

Figure 6.2: 2 GHz Antenna Pattern

The antenna gain reduction at +/- 60 degrees from the main beam of the antenna is about 8 to 9 dB. The 8 to 9 dB of reduced gain does not account for signal reflections, which may improve the antenna performance in these azimuths. Assuming no constructive benefit from reflections, the optimal antenna configuration of Figure 6.1 would still leave the interferer at a level 25 dB stronger than the minimum acceptable level for commercial receivers (34 dB – 9 dB = 25 dB). This required RF filter attenuation would still present a significant challenge to the S Band system operator, even in this unlikely scenario of optimal alignment.

Exclusion zones around BAS sites are infeasible because the BAS ENG transmitters may transmit at any location within the market. An exclusion zone approach in which the S Band base station avoids locations where an ENG transmission may occur would essentially preclude the entire market from S Band operation. Base station coordination is not a feasible approach to resolving the BAS ENG interference situation.

Similarly, earth stations located outside of BAS markets would remain a coordination obstacle for S Band base stations. The proposed shift of the S Band receive frequencies to 2005-2025 MHz would place the S Band receiver immediately adjacent the earth station transmit frequencies. Reducing the 51 dB requirement to account for the improved commercial receiver performance, the RF filter must achieve an attenuation of 36 dB with no frequency separation. Such a requirement would result in guard zones around earth stations, which would significantly reduce the serviceable market area for the band.

7. Conclusions

If the Commission were to shift the S Band uplink blocks higher in frequency by 5 MHz, this would place the S Band base station receive frequencies adjacent to high-power BAS and government transmitters above 2025 MHz. The frequency separation resulting from this shift means that the S Band base station receive filter will be unable to reject the strong nearby interference. Without adequate filtering, the base station receiver would block and suffer degraded performance, as illustrated above.

Base station coordination measures would be insufficient to manage interference, given the itinerant nature of the ENG transmissions. Exclusion zones to provide increased physical isolation from the interferers would essentially preclude service in BAS markets in the 2020-2025 MHz block. Similar issues would be encountered near earth stations transmitting above 2025 MHz.

Greater frequency separation from the high-power transmitters above 2025 MHz is essential to successfully manage the interference. A guard band of 5 MHz is essential to protect S Band receivers.

About the Author

Doug Hyslop is a partner with Wireless Strategy, LLC, providing engineering and technology strategy consulting services to wireless operators. Doug began his career in the early 1990s designing and deploying wireless systems in California and Texas. From 1999-2007, he was a director with Nextel and Sprint Nextel leading the research and testing of next generation wireless technologies. Since joining Wireless Strategy in 2007, he has assisted clients with a range of projects including wireless technology evaluation, vendor negotiation, deployment modeling, spectrum valuation, and preparation of technical studies on a range of topics from interference to technology performance to competitive evaluations. Doug holds a Bachelor of Science degree in electrical engineering from the University of Virginia.